Ms. Ref. No.: UCLIM-D-17-00016

Title: Development of the VTUF-3D v1.0 urban micro-climate model to support assessments of urban vegetation influences on HTC

URBAN CLIMATE

Dear Dr. Kerry A Nice,

The reviewers have commented on your above paper. They indicated that it is not acceptable for publication in its present form.

However, if you feel that you can suitably address the reviewers' comments (included below), I invite you to revise and resubmit your manuscript.

I would appreciate if you could submit your revised paper by Apr 03, 2017.

Please carefully address the issues raised in the comments.

If you are submitting a revised manuscript, please also:

a) outline each change made (point by point) as raised in the reviewer comments

AND/OR

b) provide a suitable rebuttal to each reviewer comment not addressed

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Yours sincerely,

Alexander Baklanov, Dr. Sci.

Editor in Chief

URBAN CLIMATE

Reviewers' comments:

Reviewer #1: Review of "Development of the VTUF-3D v1.0 urban micro-climate model to support assessments of urban vegetation influences on HTC"

The authors enabled an existing urban micro-climate model (TUF-3D) to account for vegetation effects by adding an existing tree process model (MAESPA). The work fills a gap in current micro-climate models and the authors have developed an important and useful tool (VTUF-3D). However, the article needs a great deal of work in terms of writing and organization. For example, in the model design section, the authors go into detail about the equations solved by the model but there is no way for the reader to distinguish between what was already done by the existing models and what the authors changed in the models. Also, the article is full of vague pronouns and redundant sentences. I think that the work done by the authors is important and should be published but I am not sure that the article, as it is written, is worthy of publication. I recommend that the article be accepted upon completion of major revisions. The article could be hugely improved by having someone with a background in writing/communication edit the article.

Major comments:

~~1. As mentioned above, the model design section is confusing to the reader because it is impossible to determine between summaries of the already existing TUF-3D and MAESPA models and what the authors actually changed. Since the two models (TUF-3D and MAESPA) are already published, there is no need for the authors to go into such extreme details about the equations used in each. There are too many equations and variables introduced that are not necessary in this paper. If a reader is curious they can refer to the TUF-3D and MAESPA references. I suggest that this section be reduced in terms of degree of unnecessary detail and reorganized so that the reader knows what the authors have changed.~~

**Thank you for this suggestion. We agree that the text and equations were cumbersome. We have revised the paper and have now only included the new developments applied in the creation of VTUF-3D. This includes the structure of the model and added equations. Description of a few key techniques used in TUF-3D and MAESPA were retained but highly abbreviated to give readers not already highly familiar with those models a basic understanding of how they relate to the new functionality in VTUF-3D. And much more clarification has been added to the rest of the text highlighting exactly what new methods are contained in VTUF-3D (as opposed to inherited from TUF-3D and MAESPA) to add the new functionality.**

~~2. The results section is awkwardly organized. On pg. 17 line 56 and through the rest of 18, the authors begin discussing results that are not even presented until the next section. I suggest that subsection 4.2 be incorporated into 4.1 so that the performances of each scenario can be compared without having to reference results presented later in the paper. Also, section 4.2.1 seems out of place since. It may be better to incorporate that into section 4.1 as well, in which case there would be no subsections in the results at all.~~

**Reorganised the results section as suggested (moving 4.2 into 4.1).**

~~3. The authors use vague pronouns throughout the paper that are confusing to the reader. I began listing each and suggesting alternative wording but there are too many and the task became far too cumbersome. As mentioned above, I suggest having someone with a background in writing/communication edit the article.~~

**Ahh, ok. I haven’t noticed before how often I do this. Err, I mean use indefinite pronouns. I always do a ‘which’ hunt during proofreading, I’ll have to add a pronoun check as well. So, I’ve gone over the article and eliminated as many as I could find.**

~~4. The authors use one modeled episode to validate the model. Is it possible to have a more robust validation by incorporating a few episodes? There needs to be a stronger argument that the model is validated.~~

**Due to all reviewers suggestions, I have added in the Tmrt and UTCI evaluation instead of deferring that to a future article.**

Minor Comments:

**Note: all minor changes that were addressed in the suggested manner are marked with ~~strikethrough~~ without comment.**

~~1. Pg.2 line 51 - change "…deal with" to "mitigate"~~

~~2. Pg.2 line 54 - change "Incorporating more vegetation and water into urban areas can be an~~

~~effective way to mitigate extreme urban temperatures. From an examination of a range of different studies exploring cooling effects of urban greenery (Tsiros,2010; Shashua-Bar et al., 2010; Spangenberg and Shinzato, 2008), it is clear that increased vegetation and water can have positive benefits, from the city-wide scale down to a micro-climate street level scale (Coutts et al., 2012). Shading and evapotranspiration are cited as the main drivers of these cooling effects (Bowler et al., 2010)." to "Incorporating more vegetation and water into urban areas can effectively mitigate extreme urban temperatures on local to micro scales (Tsiros,2010; Shashua-Bar et al., 2010; Spangenberg and Shinzato, 2008; Coutts et al., 2012)"~~

~~3. Pg 3 line 35 - The authors mention how quickly VTIF-3D runs but to not give any other model run times to compare.~~

**Good point, I had assumed a familiarity with CFD modelling. Added that CFD modelling would take at least an order of magnitude more.**

~~4. Pg 3 line 37 - Remove the sentence beginning "This approach needs…" because it is a bit redunda~~nt.

~~5. Pg 3 line 45 - Define MEASPA~~

**Tried to clarify in the text. MAE is not an acronym (came from MAESTRO model which was just a name), while SPA (Soil-plant-atmosphere) is.**

~~6. Pg 3 line 49 - the part of the sentence "…around identifying how…" is awkwardly worded.~~

~~7. Pg 4 line 6 - Remove first three sentences of the section as they are redunda~~nt.

~~8. Pg 4 line 12 - The sentence beginning with "The vegetation functionality…" is vague and confusing. Suggest rewording with a bit more precision.~~

~~9. The entire Model Design section has many variables defined in the text that are not used in the equations. These are not needed and should be removed from the text.~~

**The equation section has been heavily edited and non-relevant variables removed.**

~~10. Section 2.5 title should be words not variables that the reader needs to go look up~~

~~11. Equation 14 is vague. All it says is that UTCI is a function of those variables but gives no detail as to how it is calculated. Also, UTCI is not discussed at all in the results so this may not be needed anyway. I suggest either making equation 14 show the actual calculation or removing it entirely.~~

**Ok, I agree that the UTCI function is not useful. The actual equation is about a page long and documented in the citation. I’m happy to remove the actual equation (UTCI function) and point to the equation source.**

**However, due to comments from all reviewers about including the 2nd evaluation of Tmrt and UTCI in this paper, I have added that section in as well (instead of deferring that to the next article). This makes the Tmrt and UTCI discussion very relevant.**

~~12. Pg 10 line 57 - "…ray-traced from the centre of each quarter…" to where?~~

**Clarified that ray traces are performed 4 times towards the sun for each surface.**

~~13. Pg 11 line 33 - What specific forcing data is supplied and is that easy to come by?~~

**Added (such as described in the Pr04Val evaluation in Section \ref{sec:modelsetup})**

~~14. Section 3.1 should be titled "Validation Data"~~

~~15. Pg 12 line 9 - First word should be "The" not "A".~~

~~16. Pg 12 lines 52 to 53 - Reword the sentence "An analysis by Nury…". An analysis of what?~~

~~17. Figure 5 is not needed~~

~~18. Pg 14 line 46 - The sentence is confusing. Reword using more precise language.~~

~~19. Section 3.3 is strange because it is titled "validation approach" but begins by discussing other scenarios other than the validation run. Suggest rewording the first sentence so that the reader is not immediately introduced to model scenarios when they are expecting to read about validation approach.~~

~~20. Pg 15 line 33 - Remove sentence "This will allow an …" because it is redundant~~

2~~1. Pg 15 line 34 - The sentence "As discussed earlier in this section…" should be moved to the results or the conclusion section. Also, remove "As discussed earlier in this section" so that the sentence reads "The Intercomparison project…"~~

~~22. Pg 16 line 56 - The sentence "In terms of…" is strangely worded and should be rewritten. The next sentence is also strange and there is no way to tell which numbers are modeled and which are observed.~~

~~23. Pg 17 line 3 - No need to define index of agreement as "d" unless there is a formula showing how "d" is calculated. Also, there is no discussion of what these metrics actually mean and there ought to be, otherwise they are just numbers.~~

**Moved brief index of agreement overview to evaluation approach section and added brief introduction to 0-1 scale to first usage of index.**

~~24. Pg 19 line 52 - The sentence "These modifications allow…" should be removed because it is redundant.~~

~~25. Pg 21 line 4 - The sentence "Significantly, in this…" is strangely worded and should be rewritten.~~

Reviewer #2: Development of the VTUF-3D v1.0 urban micro-climate model to support assessments of urban vegetation influences on HTC

Nice et al.

The authors further develop an established microscale urban climate model to include trees, vegetation and fair weather hydrology, for the purposes of detailed examination of effects of vegetation and water implementations in street canyons on microclimate and thermal comfort. Overall, this is a very detailed and careful work. Nevertheless, a few key details appear to be missing in the model description, particularly with respect to the vegetation treatment. As well, the model evaluation is performed at a different scale from the intended use of the model. Provided the main comments are sufficiently addressed, this work deserved to be published.

General questions/comments

~~Do trees shade surrounding surfaces via these stacks of blocks depicted in Fig. 1 (e.g., ignoring tree shape, which is represented in MAESPA?). Can trees shade building roofs? What happens to radiation scattered/reflected by trees? Do trees intercept longwave/reflected shortwave radiation between building surfaces? Please clarify in the text.~~

**Figure 3 shows the interactions between vegetation and building and ground surfaces, as well as being detailed in section 2.5.1. The figure (panels c and d) do not show ray traces from roof surfaces, but ray traces are performed from all surfaces towards the sun and if vegetation is encountered, a reverse ray trace allocates energy downward. So, yes trees will shade roofs.**

**Paragraph 2 of section 2.2 mentions that scattered shortwave radiation is currently disregarded.**

**Longwave interactions with vegetation are handled entirely within the offline MAESPA vegetation modelling and not explicitly dealt with by VTUF-3D. The differential shading method (paragraph 4 of section 2.5.1) attempts to account for these variations.**

~~How interactive are the two models in time? Do they interact each timestep? Please clarify further in the text.~~

**The two models do not interact directly, as the vegetation modelling is done offline before the main model run. Section 2.5.1 paragraph 4 spells this out, as well as the rationale behind modelling each vegetation item twice (with full incoming radiation and with diffuse only). So, the models do not directly interact, but VTUF-3D does use different offline vegetation model results depending on whether that vegetation would currently, within the timestep, be illuminated or not. I have also added a number of times in the text that vegetation is modelled offline to try and relieve possible confusion about the interactions better.**

~~Ultimately, is energy conserved in both models (VTUF-3D and MAESPA)? This is a common basic test of any model with energy flows/storage, and should be one of the first tests performed in a model evaluation; it should be mentioned if you have performed one, and performed if you have not. There is some casue for concern here I think because some energy balance terms are computed differently in the two models.~~

**Yes, this test was performed, but not presented. Added “tests were performed (not presented here) and found the model conserved energy despite different sources of modelled fluxes.”**

~~Evaluation of VTUF-3D is performed against local-scale fluxes (overall surface-atmosphere exchange), whereas the model is clearly designed to represent detailed microclimates in street canyons (and associated thermal comfort). How does this overall evaluation yield confidence in the model at the microscale/street canyon scale? The calculation of thermal comfort indices is never evaluated, for example, or surface temperatures in the canopy. Please comment in the text why this dataset is chosen, and is possible test against a dataset at the desired scale of application. [I now notice that this is addressed in the conclusions. Please include this context at the start of the evaluation section. I also suggest that the UTCI treatment in Sect. 2.5 is removed and instead introduced in the subsequent article where UTCI is evaluated.]~~

**As the UTCI predictions are a critical component of the work VTUF-3D was designed to perform, and due to many comments from all reviewers, the Tmrt and UTCI evaluation was added to the article. This evaluation combined with the flux evaluation should demonstrate confidence in the predictions at a micro-scale, both temporally and spatially. I originally thought this would make the article too long but appears to be necessary to address concerns expressed in this comment (and others). As mentioned in section 3.1, the Preston flux data was chosen as evaluations against flux observations are considered a fundamental evaluation technique. In addition, the Preston dataset is well regarded and widely used in model evaluations such as the Grimmond et al (2010) and Best & Grimmond (2012) inter-comparison project. This also allows comparison to the Best & Grimmond (2012) results.**

~~In general, the Mean Absolute Error (MAE) is recommended over the RMSE. See Willmott et al. (2009). I suggest calculation of MAE instead of RMSE.~~

**Added calculations of MBE (in addition to MAE) in order to compare to Best & Grimmond (2012) who use RMSE and MBE.**

~~The writing is a bit wordy and could be simplified in many locations.~~

**Yes, reviewer #1 pointed this out as well. I’ve given the article another thorough edit, simplifying, removing indefinite pronouns, passive voice, etc.**

~~Title: HTC -> human thermal comfort~~

Line by line comments

~~P5L36-37: This sentence is unclear - 'matched'? The analytical equations are for what? View factors?~~

**Simplified description in the text, as this functionality exists in the original TUF-3D model.**

~~P5L45-46: What happens to the radiation scattered by the tree? Does it impinge on other surfaces surrounding the tree?~~

**Added clarification, scattered radiation is currently not distributed in VTUF-3D.**

~~P6L41: "thought" seems wrong~~

~~P7L43: Change to "suitably"~~

~~P8L32: "iterative converging Tcan…"? Please clarify.~~

**Simplified. Replaced Tconv with Tcan. The iterative converging method to calculate Tsfc then Tcan is fully contained in original TUF-3D model, so is not necessary to detail in this article.**

~~Eq. 8: Does this yield the same heat flux from vegetation as is calculated by MAESPA? If not, please justify your approach.~~

**Testing of MAESPA found that the sensible heat fluxes were somewhat unreliable, while Qe performed quite well. Using this and in order to keep the consistency of the approach for sensible heat fluxes already employed for non-vegetated surfaces, see Eq (4), using the modelled MAESPA surface temperature of the canopy was found to work well. In addition, correct modelling of heat storage of the canopy and woody biomass in trees was far too complex. The method to maintain our consistency was to model this as a residual, which also assisted in energy balance closure.**

~~Eq. 10: The "2/Tm" portion of the equation does not fit. The storage at street surface should not depend on the temperature of the deepest layer, but should instead be a thickness such that you have a gradient dT/dz. The "2" is unclear. Please check/correct/explain further.~~

**This is something unchanged from the original TUF-3D (Krayenhoff 2007). As such, it has been removed from this manuscript as part of the overall removal of all already published portions of the model (see Reviewer #1, major comment #1).**

~~Eq. 11: Third term on RHS seems incorrect. Why A/4 and not A/2? Surely half of the sphere is illuminated. Please check. Secondly, presumably the exposure of a pedestrian in the canyon will differ from the surfaces themselves, and this deserves a contextual comment in the text. Furthermore, Tmrt usually involves a weighting by the direction of the incoming radiation (see VDI guidelines/Rayman articles by Matzarakis). If this is not included, it should be acknowledged in the text.~~

***The third term on the RHS is correct and follows Liljegran et al., 2008 and relates to the direct irradiance on the projected area of the globe. Please see below.***

***Regarding exposure of a person compared to a surface, yes there is likely to be some differences, however Tg and Tmrt therefore are calculated per grid square, so there is variance across the domain. The assumption is that the radiation leaving a surface (e.g. a wall) reaches the person (sphere) located at each grid point.***

***The use of a sphere is a simplification of the calculation of Tmrt on the human body and so the weighting factors usually applied for the calculation of Tmrt for the human body are instead those for a sphere.***

***From Liljegren, J. C., Carhart, R. A., Lawday, P., Tschopp, S., Sharp, R., 2008. Modeling the wet bulb globe temperature using standard meteorological measurements. Journal of Occupational and Environmental Hygiene 5 (10), 645–655.***

***“The second and third terms on the right represent the energy gained by the globe due to diffuse and direct solar irradiance. It is important to note that these act on different areas: the diffuse irradiance is incident on the upper hemisphere of the globe, whereas the direct irradiance is incident on the projected area of the globe normal to the solar zenith angle, which is the crosssectional area of the globe, πD2/4.”***

~~P10L52-P11L8: This section seems unnecessarily wordy and is not exceptionally clear. I recommend rewriting it and focusing on the essentials.~~

**Rewrote the paragraph to clarify the important points.**

~~Fig. 3: Does vegetation/trees affect exchange between building surfaces? Please clarify. Also, text in Fig. 3d is too small~~.

**Increased font sizes.**

~~P11L12: "...in the initial ray tracing…"~~

~~P11L11-16: What about vegetation effects on radiation exchange between building/road surfaces?~~

**Added additional clarifications. Radiation exchanges proceed normally using TUF-3D methods if no vegetation is encountered. Otherwise, additional processing determines radiation exchanges between surfaces and intervening vegetation.**

~~P11L27-29: This sentence needs clarification, particularly "zero to many surface interceptions".~~

**Yes, that was probably written as by a (former) software engineer. The sentence wasn’t really necessary, took it out.**

~~P11L32-33: Diffuse exposure will be affected by changes to the sky view (e.g. a tree beside a large building will receive much less diffuse). Is this accounted for? Please explain/justify in the text.~~

**No, with only two variations, there will be some variations that are not exactly captured. Added “However, these variations will not be able to exactly capture every variation, such as a reduction in diffuse shortwave due to a nearby building.”**

~~P11L33-39: Please communicate this more clearly - I cannot understand what is happening.~~

**Rewrote the paragraph to clarify and removed some unnecessary confusing details.**

~~Sect. 3.1: Consider using "evaluate" instead of "validate" throughout the section/article. Can a model ever be shown to be 'valid' for all situations it might be applied?~~

~~P12L12-13: Presumably the radiation measurements are much more local.~~

**Yes, and this was a concern about this approach and dataset. But given the very homogeneous nature of the observed area and the positive results from the evaluation, this gave us confidence the model’s ability to capture the fundamental driving forces in the area. In addition, the now added evaluation of Tmrt and UTCI using a micro-climate dataset (as mentioned in numerous comments) showed that the model also performs well spatially and temporally against micro-climate observations of Tmrt and UTCI.**

~~Table 3: Why is internal floor temperature needed if internal air temperature is constant?~~

**This is just a piece of the original TUF-3D model. It is assumed the building interiors are kept to a constant temperature and can impact the amounts of anthropogenic heat generated.**

~~P14L47: I don't think "pluggable" is the appropriate word.~~

~~P15L11: Do these global shortwave values match those measured at Preston and used to force the rest of the model? If not, energy will not be conserved in the model. Yes, this issue is seen later at P16L22-24.~~

**Conservation of energy was also raised by the general comments of reviewer #2. I added a comment to the article that conservation of energy was tested but not presented in the article. The concern is that TUF-3D and MAESPA are different sources of fluxes but this was not found to be a problem. In normal operation of the model, the special circumstances requiring dual sources of forcing data in the Preston evaluation to compare the performance against the observation shouldn’t be necessary and this potential energy conservation problem will not be applicable.**

~~P15L47: Does VTUF not account for interaction radiatively between the two models at each timestep?~~

**Repeating the response to general comment #2 for reviewer #2:**

**The two models do not interact directly, as the vegetation modelling is done offline before the main model run. Section 2.5.1 paragraph 4 spells this out, as well as the rationale behind modelling each vegetation item twice (with full incoming radiation and with diffuse only). So, the models do not directly interact, but VTUF-3D does use different offline vegetation model results depending on whether that vegetation would currently, within the timestep, be illuminated or not. I have also added a number of times in the text that vegetation is modelled offline to try and relieve possible confusion about the interactions better.**

~~P16L58: Units: 294 W m-2.~~

~~P17L4: "The index of agreement, d, …" This is not an error analysis, formally.~~

~~P21L21-27: The local-scale evaluation does not support this, in my opinion, but the planned evaluation focused on Tair and UTCI will. Remove this paragraph and include it in the subsequent publication?~~

**Due to comments from all reviewers, the Tmrt and UTCI evaluation has been added instead of deferring it to a future article.**

References

Willmott CJ, Matsuura K, Robeson SM, 2009: Ambiguities inherent in sums-of-squares-based error statistics. Atmos Environ 43, 749-752.

Reviewer #3: This paper presents a detailed explanation and validation of the VTUF-3D model. This model builds upon the functionality of the MAESPA tree process model, but introduces new functions to incorporate enhanced tree shading and evapotranspiration components to adequately model the impact of urban greening on human thermal comfort. The model is well constructed and validated using field observations, and is shown to perform well with only minor limitations.

I believe this model is impressive, and goes a long way toward filling some significant shortcomings of urban canopy modeling. I approach this article from the perspective of urban planning and scenario modeling, and I must admit I have been often underwhelmed by many modeled greening scenarios. In particular, my experience with WRF scenario modeling literature and research has often tended to find albedo far more effective than greening in reducing urban temperatures. This paper helps to confirm my understanding that this type of modeling has not handled the benefits of shading well, which may be why greening scenarios often underperform. This approach gives me far more confidence in the ability to model temperatures in the urban canyon, and I am excited to see its future application.

~~That being said, I do believe there are some opportunities to strengthen the argument for this method as a tool for planners. The literature review is well structured, and contains many of the papers that came to my mind as I began reading this paper. However, I wanted to call your attention to some other relevant literature beyond Bowler et al. (2010) for your literature review. Regarding tree orientation for cooling and energy savings, I think Donovan & Butry (2009), Rosenfeld & Romm (1996), and Simpson & McPherson (1996) could help structure your argument about optimizing tree orientation. Additionally, Oliviera et al. (2011) and Sanusi et al. (2015) regard specifically street tree orientation and cooling ability. In regards to the QE limitations around page 18, just a few studies came to mind that could inform improvements to the watered impervious surface component: Nakayama et al (2010) and Kim et al (2012).~~

**Thanks for these suggestions. I’ve added some added discussion around trees and energy usage to the introduction based on those.**

**Now that the micro-climate Tmrt/UTCI validation section has been added, the street orientation suggestions were useful in revising the overview section of that validation (section 3.2).**

**I didn’t use your suggestions of Nakayama et al (2010) and Kim et al (2012) since we didn’t attempt to model permeable pavement. I did file those away for future model enhancements to include those features (which are common WSUD features). However, your suggestion reminded me of Hendel et al. (2016), who’s observations after pavement watering found maximum air temperature (at 1.5m) reductions of 0.79C as well as 1.67C Tmrt and 1.03C UTCI. So I added:**

**“In other parameters, there is evidence that wet impervious surfaces can have some other short term cooling impacts. \cite{Hendel2016} observed that hourly watering of urban pavement during heat wave conditions could deliver maximum air temperature reductions (at 1.5m above ground level) of 0.79 \SI{}{\degreeCelsius} as well as $T\_{mrt}$ and UTCI reductions of 1.67\SI{}{\degreeCelsius} and 1.03\SI{}{\degreeCelsius}. While this might indicate an upper bound to the impact of wet pavement, until this portion of precipitation received is accounted for in the model, care should be taken when modelling periods which contain precipitation.”**

~~Finally, regarding your discussion, I believe it would help to provide some specific examples regarding how you see this tool being used by planners. Since your paper is framed as a way to enhance planning strategies to combat heat in a changing climate, it is important to make this connection at the end as well to reach out to the planning community. It is documented in the literature that planners often lack the personal expertise, personnel or time to run and interpret complex models such as the one you have created (Eliasson, 2000; Moser, 2014; Winkler, 2011). Even a short discussion about partnerships or other methods of implementation would go a long way to enrich the discussion. In terms of utility, I would like to see this model used in the species selection process. You currently use existing species in the validation procedure, which makes sense in the context of this paper. But current species may not always be appropriate in a changing climate. This tool could be useful to determine the impact of various species that may be more appropriate in the future under a new climate regime. Similarly, I see this tool being most useful for long-term planning goals rather than short-term emergency response. I think you will need to further explain your reasoning on page 21, line 26 regarding this model's utility in emergency planning in order to convince planners that it can be used in such a case.~~

**The comment about extremes originally drew on a larger lit review which had a longer discussion about temperature thresholds and human health (i.e. Nicholls et al., 2008; Loughnan et al., 2010). In this more abbreviated form, I’ve changed that to a more general comment about “understanding how current urban design will respond to changing urban climate conditions.” The initial design goal of the model was to examine short (less than a week) extreme temperature events, which coloured some of the overall discussion in the drafts, but there is no need to restrict the usage of the model to only these scenarios.**

**I think I should defer the larger discussion of species selection to the follow up article, which include an evaluation using observations of single isolated trees and scenarios of canopy cover. It seems like this article is already pretty long and complex and it would be quite difficult addressing species in a meaningful way here. As I’ve had to pull quite a lot of what was already planned for the 2nd article, that discussion seems like it would fit well there.**

**I think the suggestion about drawing out the future uses and future users is a good way to sum up this article. I hadn’t quite figured out how to include that sort of detail but I was able to turn this suggestion into my final paragraph for the article.**

**“However, the creation and evaluation of VTUF-3D is only a first step. As the intended end users of the knowledge gained through VTUF-3D, planners and policy makers, often lack the time, expertise, and scientific rigour needed to generate and interpret climate model output \citep{Elasson2000,Moser2014,Winkler2011}, additional work will need to be done with VTUF-3D to systematically analyse a wide variety of scenarios seeking optimal uses of urban vegetation for HTC and summarise these findings. A forthcoming article will start this process with an examination by VTUF-3D of varying urban canopy cover on HTC in street canyons. VTUF-3D has also adopted by the CRC for Water Sensitive Cities as their micro-climate tool to evaluate climatic impacts of WSUD, with the findings disseminated to industry partners and the public at large. Finally, work is under way to provide a simpler user interface to VTUF-3D, allowing a wider adoption beyond the current academic research user-base.”**

Aside from the above recommendations, I believe this is a strong paper and a promising model.

Detailed notes:

~~Abstract line 17: remove "future" as this sentence describes trends already occurring~~

~~Abstract line 23: Spell out MAESPA acronym for its first use~~

**SPA is Soil-plant-atmosphere but MAESTRO doesn’t stand for anything (Wang, Y.P. and Jarvis, P.G., 1990. Description and validation of an array model - MAESTRO. Agric. For. Meteorol., 51: 257-280.)**

~~Page 1 line 44: change "increases" to "growth"~~

~~Page 1 line 50: "In addition, climate trends point toward…" or "In addition, average and extreme temperatures are increasing in a changing climate"~~

~~Page 1 line 53: "shifting toward a more elderly population" (older and elderly seem similar to me)~~

~~Page 2, line 50: (passive voice) "In coming years, cities and their residents will need to adapt to…"~~

~~Page 3, line 46: spell out MAESPA acronym the first time~~

**(amalgamation of the MAESTRO and SPA (Soil-plant-atmosphere) models). See Abstract line 23 comment.**

~~Page 14, line 3: change "uncertainly" to "uncertainty"~~

~~Page 17: lines 56-57: change to "It is anticipated that this method of tiling out and incorporating vegetating into a micro-scaled surface energy balance model will bring performance…" As it is now, this sentence is very long.~~

~~Page 18, line 3: change to: "The results suggest that this is the case" (current awkward phrasing)~~

~~Page 18, line 39: use some language to quantify (roughly) the amount of uncertainty here. As stated, I do not know how big a concern this uncertainty would be.~~

**This paragraph has been removed. These uncertainties should be addressed by the response to P12L12-13 of reviewer #2.**

~~Page 18, lines 39-40: "because of the nature of both" is unclear to me. Perhaps "because of inherent uncertainties to both approaches"~~

~~Page 21, lines 23-24: remove "can be developed" at the end of the sentence. Currently not in agreement with the beginning of the sentence. Or, replace with "… how best to best use urban greenery to reduce urban temperatures."~~

~~Page 21, line 26: Please expand on how this model can be used to plan for emergency responses. Currently, this could be overstating the utility of the model, as I see it far more likely to be used as a long-term planning tool, rather than a short-term emergency response tool.~~

**I replaced the emergency response with understanding how the urban designs respond to extremes. One of the major intended uses of the tool (and major effort in evaluating model performance) is to examine short term extreme heat scenarios.**

References:

Donovan, G. H., & Butry, D. T. (2009). The value of shade: Estimating the effect of urban trees on summertime electricity use. Energy and Buildings, 41(6), 662-668. <http://doi.org/10.1016/j.enbuild.2009.01.002>

Eliasson, Ingegärd. (2000). The use of climate knowledge in urban planning, Landscape and Urban Planning, Volume 48, Issues 1-2

Kim, R., Park, J., Jung-soo, M., & Jung-hun, L. (2012). Reduction Effects of Urban Heat Island by Water-Retentive Pavement. Materials Science Forum, 724, 147-150. <http://doi.org/10.4028/www.scientific.net/MSF.724.147>

Moser, S. C. (2014). Communicating adaptation to climate change: the art and science of public engagement when climate change comes home. Wiley Interdisciplinary Reviews: Climate Change, 5(3), 337-358. <http://doi.org/10.1002/wcc.276>

Nakayama, T., & Fujita, T. (2010). Landscape and Urban Planning Cooling effect of water-holding pavements made of new materials on water and heat budgets in urban areas. Landscape and Urban Planning, 96(2), 57-67. <http://doi.org/10.1016/j.landurbplan.2010.02.003>

Oliveira, S., Andrade, H., & Vaz, T. (2011). The cooling effect of green spaces as a contribution to the mitigation of urban heat: A case study in Lisbon. Building and Environment, 46(11), 2186-2194. <http://doi.org/10.1016/j.buildenv.2011.04.034>

Rosenfeld, A. H., Romm, J. J., Akbari, H., & Pomerantz, M. (1996). Policies to reduce heat islands magnitudes of benefits and incentives to achieve them. ACEEE Summer Study on Energy Efficiency in Buildings, 9(18), 177-186. Retrieved from <http://energy.lbl.gov/EA/reports/38679.pdf>

Sanusi, R., Johnstone, D., May, P., & Livesley, S. J. (2015). Street Orientation and Side of the Street Greatly Influence the Microclimatic Benefits Street Trees Can Provide in Summer. Journal of Environment Quality, 0(0), 0. <http://doi.org/10.2134/jeq2015.01.0039>

Simpson, J. R., & McPherson, E. G. (1996). Potential of Tree Shade for Reducing Residential Energy Use in California. Journal of Arborculture, 22(1), 10-18.

Winkler, J.A., G.S. Guentchev, M. Liszewska, Perdinan, and P.-N. Tan. (2011): Climate scenario development and applications for local/regional climate change impact assessments: An overview for the non-climate scientist. Part II: Considerations when using climate change scenarios. Geography Compass, 5/6, 301- 328. DOI 10.1111/j.1749-8198.2011.00426.x.